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The Level of Impact Noise and Threshold Characteristics Nonlinear Assessment Signal Parameters

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Abstract. The article deals with the effect of noise which influences the system with simple signal formation, the output characteristics of the system. The system is further subject to nonlinear signal transformation. We received results and carried out analysis of signal/noise ratio at the output of the system with linear and non-linear release of the information signal parameters, such as amplitude, square amplitude, phase and double phase. We studied the effect of noise bandwidth of the linear part of the system and the noise bandwidth of the system after the nonlinear transformation on the signal/noise ratio at the output of the system. We analyzed thresholds valuations of signal/noise ratio at the input of the nonlinear part, limiting the area of noise signal suppression at its output.

1. Introduction

Evaluation of information parameters of signal such as amplitude and phase of signal are usually produced using methods of non-linear transformations. As a result, there is a change of the signal/noise ratio (SNR) of the process, at the output of nonlinear device. Character of this process often depends on the type of non-linear transformations. In the paper we analyze the effect of noise at the input of the system on change the SNR in the nonlinear transformation of various types of signal and threshold characteristics. The purpose of the research is to analyze changes in the SNR with the non-linear transformation of signal.

2. Experimental

Mathematical description of the processes in nonlinear systems, including analysis of the interaction between the signal and noise; and the calculation of the ratio of their capacities, is a very difficult task, which is usually solved by numerical methods or methods of mathematical modeling. In the work mathematical modeling methods have been used. For the research were selected narrowband partially correlated narrowband processes. The signal was obtained by submitting blank noise on shaping filter. Further blank noise, which simulates the effects of noise on the system, is added. The resulting mixture of signal and noise is supplied to the non-linear converter (Figure 1). There was selected standard polynomial nonlinear conversion power in the research of the following form (1):

$$i = a_0 + a_1 \cdot U + a_2 \cdot U^2 + ... + a_n \cdot U^n, \qquad (1)$$

where i is received signal, U is the signal amplitude, a is approximating coefficients.

It is assumed that the information lies in the fluctuation component of the process at the nonlinear element output, where the correlator that calculates the centered process step autocorrelation function (ACF) with much less than the information process interval correlation, is used to separate that component. In this case the ACF values at zero shift is equal to the total signal power and interference [2–4].

When a shift is not zero, the ACF values at a sufficiently large averaging interval are determined only by the signal because the noise component value at divergent moments of time are uncorrelated and make it possible to estimate the information signal power.

ACF calculations were done using Equations 2–5. Formulas allow us to calculate information parameters of signal such as amplitude, double amplitude, phase and double phase. Represented as set of samples of instantaneous values of the values of sine and cosine component signal.

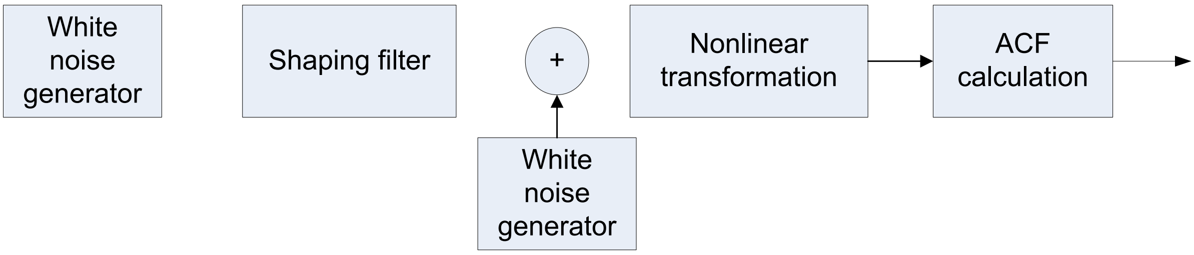

Figure 1. Studied model block diagram.

As an example Figure 2 shows the ACF process at the output of the nonlinear element that provides a signal amplitude assessment according to the Equation [5]:

$$U_i = \sqrt{Uc_i^2 + Us_i^2}\,, \tag{2}$$

where U_i is signal amplitude counting, Uc_i is the instantaneous value of the cosine component signal counting, Us_i is the instantaneous value of the sine component signal counting;

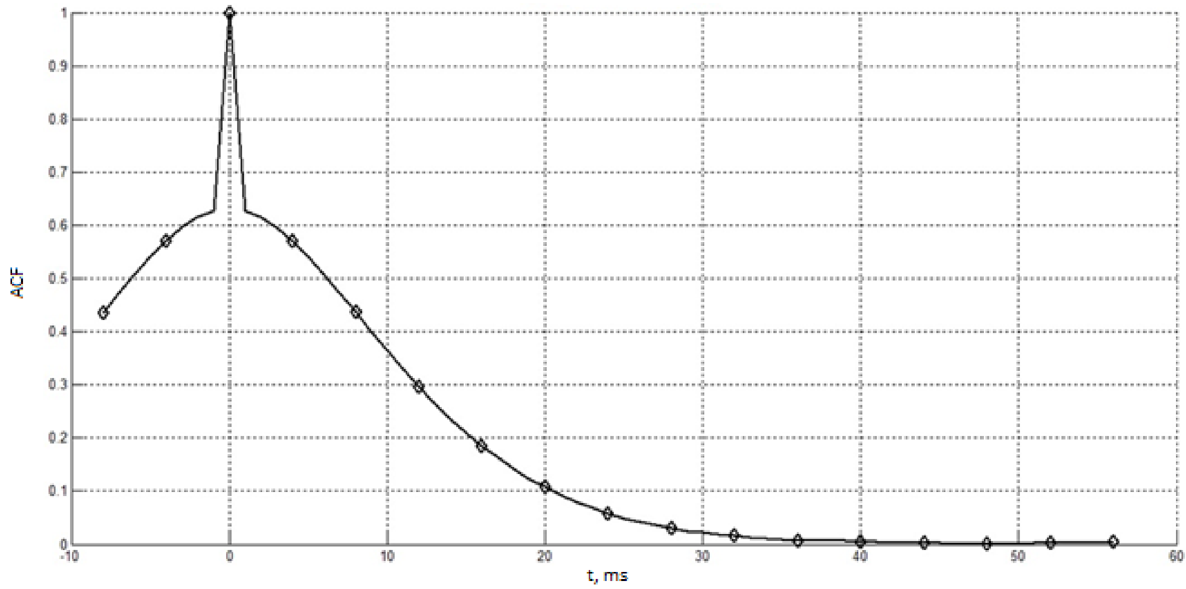

Figure 2. Type of the investigated signal autocorrelation doubled phase.

3. Results and considerations

Four signal characteristics have been taken as information system parameters: the amplitude, square amplitude, phase and double phase, with different signal-to- noise ratio of the system. Besides of the amplitude as an information parameter we consider: squared amplitude, the cosine of the signal phase and the cosine of the doubled phase, calculated according to the Equations (3)–(5) [1–3]:

$$U2_i = Uc_i^2 + Us_i^2, \tag{3}$$

$$C\varphi = \frac{Uc_i}{\sqrt{Uc_i^2 + Us_i^2}}, \tag{4}$$

$$C2\varphi = \frac{Uc_i^2 - Us_i^2}{Uc_i^2 + Us_i^2}. \tag{5}$$

Comparative analysis ACF was performed for various parameters of the signal in the absence of noise and the presence of noise.

As might be expected, in the absence of the noise component in the system, cross-correlation functions (correlation function of sine and cosine component correlation functions sine and cosine phases) are zero, and in the presence of noise there is a correlation between the quadrature components of the signal, which depends on its size.

By the results of the experiment, it was determined that according to the ACF figure we can measure the influence of noise on the system. According to the peak of the ACF we calculate value of the power signal and the amount of noise. At the level of the base of the peak we calculate signal strength. As a result, it is easy to make calculation of the noise power affecting the system as a difference between total power and signal strength (Figure 3).

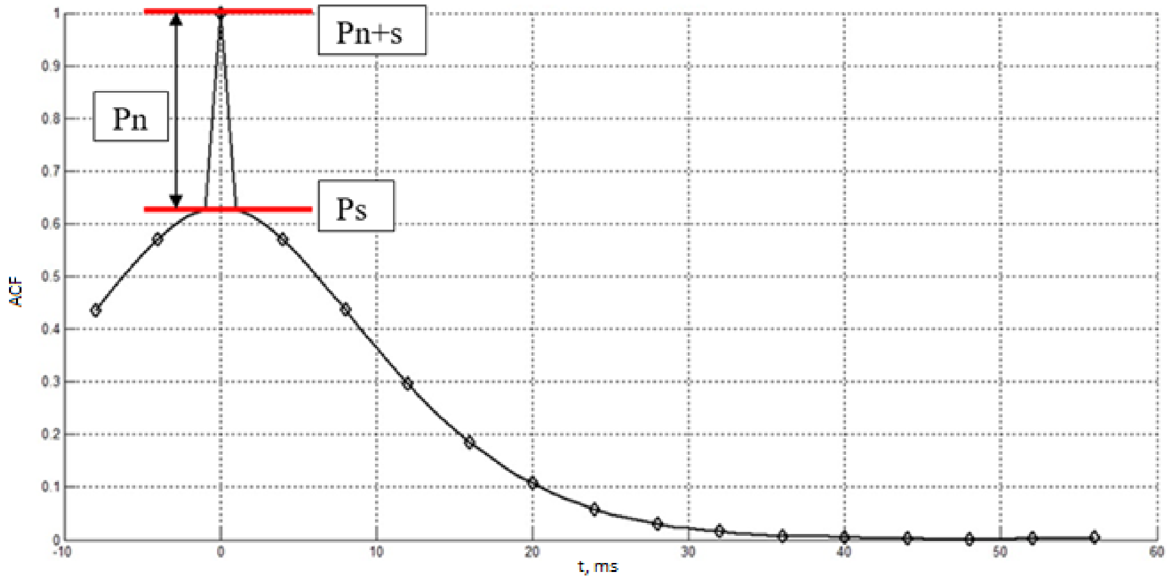

Figure 3. The method of calculating noise power.

On the basis of the realized system, we studied dependence of the SNR at the system output and the SNR at the input of the nonlinear transducer. Plots at Figure 3 show the dependence of the SNR at the output of the nonlinear transducer upom the SNR at the input for various information signal parameters.

The research was conducted by comparing the experimentally obtained data graphically, comparing the mean square error and relative standard error. Figure 4 shows graphs of the SNR at the output of the nonlinear transformer SNR at the input of various information parameters of the signal.

Particular attention should be paid to the range where the Signal-to- Noise Ratio input value does not exceed 10÷20. The graph at Figure 3 is depicting the dependence of the SNR at the output and input of the system for the specified interval.

From these graphs we can see that the smallest decrease in Signal-to- Noise Ratio occurs with using the amplitude and phase, in these cases the average values are not declined by more than 2–3 times. Whereas as the use of a squared amplitude and doubled phase gives a ratio decrease to 4–8 times. The SNR change can be called a system loss. For the amplitude and phase information parameters this values are the smallest, and for the squared amplitude and double phase they are considerably bigger. It is noteworthy that when the SNR value at the input is less than 2, the system loss increases significantly.

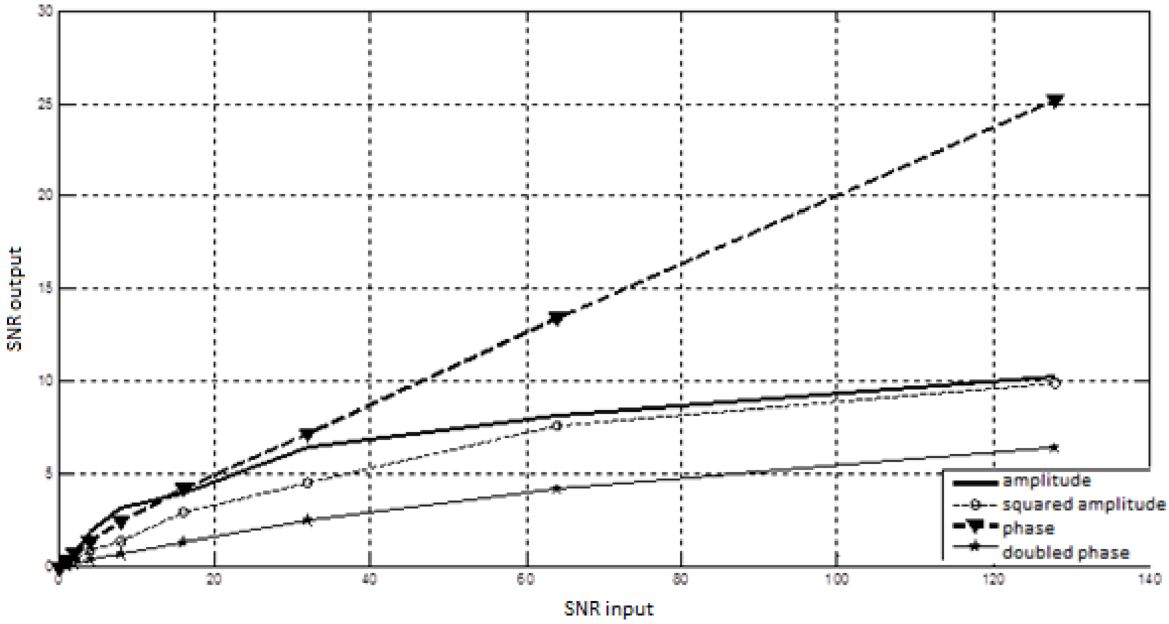

Figure 4. The dependence of the SNR at the input and output of the nonlinear transducer.

Phase signal received as an information signal parameter in the modeling of systems with non-linear signal processing is a promising information parameter in correlation velocity meter, because it does not impose any restrictions on the choice of an automatic gain control parameters and signal strength, and has the smallest width of CCF.

As a consequence, the use phase of the signal as an information parameter of signal allows you to avoid errors in the processing of the signals received at modeling reflected by extended surface. It is worth to note that the dependence of the SNR on such information parameter, as the signal phase, is linear. This fact can be used in the processing of information and simplification of correlation gauges.

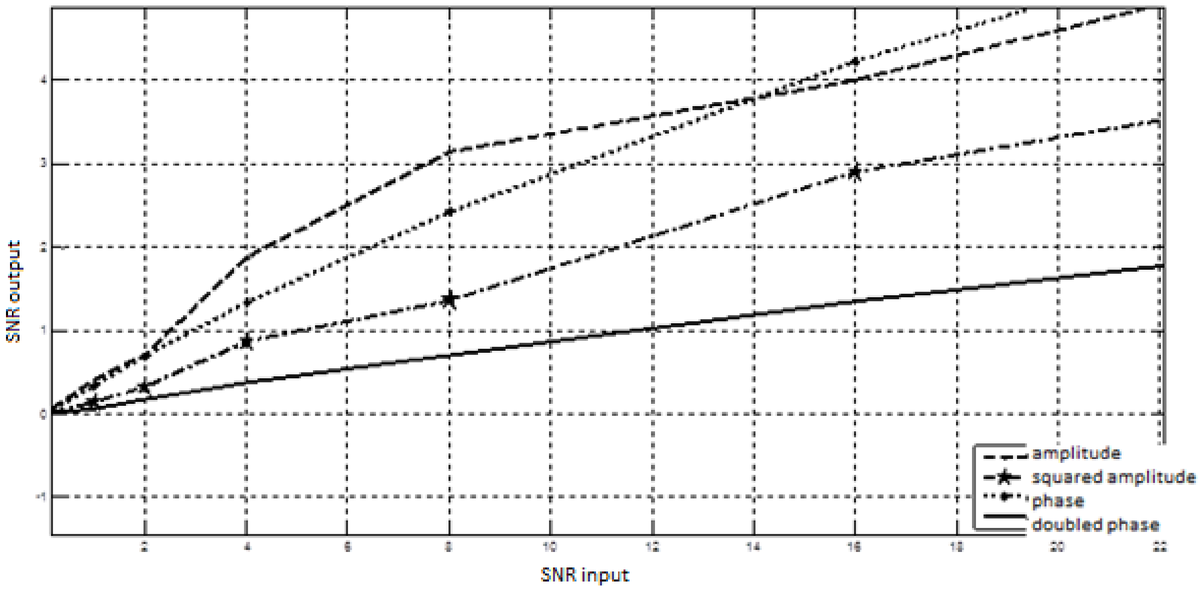

Figure 5. The dependence of the SNR at the system output from the SNR on the system input for the critical interval limited 20.

4. Summary
These results must be considered when modeling systems with signals reflected by extended surface and correlation measurement of parameters (speed, altitude, etc.). When modeling systems with reflected signals, you need to take into account the effect of noise; that's why when using non-linear signal processing methods you should provide at least 6 SNR at the input of such systems.

Increasing the level of interference, determined by random dispersion of the input signal, reduces the useful signal at the output of the nonlinear element. The threshold effect for the considered values of the SNR at the input are not observed.

Increasing the value of the SNR at the input of the system has greater influence on such information parameters, as double phase and square amplitude. These results suggest a promising use of the phase component of the signal as information parameter in the processing and simulation systems research of signals, reflected by extended surface.

References
[1] Helstrom C W 1968 *Statistical Theory of Signal Detection* (Oxford: Pergamon Press)
[2] Jackson L B 1989 *Digital Filters and Signal Processing* (Boston: Kluwer Academic Publishers)
[3] Antolovic D 2010 Radiolocation in Ubiquitous Wireless Communication (US: Springer)
[4] Oppenheim A V and Schafer R W2010 *Discrete-Time Signal Processing* (Harlow: Pearson)
[5] Bykov V V 1971 *Digital modeling in statistical radio engineering* (Moscow: Sovetskoe radio) (in Russian)
[6] Akimov P S *et al* 1984 *Theory of signal detection* (Moscow: Radio i svjaz') (in Russian)
[7] Timoshenkova Y S *et al* 2015 *Proc. CriMiCo* **1** 937 (in Russian)
[8] Hayes M H 1996 *Statistical Digital Signal Processing and Modeling* (New York: John Wiley & Sons)
[9] Karam L J *and* McClellan J H 1995 *IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing* **42(3)** 4937837 DOI: 10.1109/82.372870
[10] Ustinova I *and* Kozlova A 2016 *IOP Conf. Ser.: Mater. Sci. Eng.* **142(1)** 012027 DOI:10.1088/1757-899X/142/1/012027